Energy Efficient Maneuvering Of Connected And Automated Vehicles With Situational Awareness At Intersections

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Overview

Timeline

- ***Start date:*** October 1, 2019
- ***End date:*** December 31, 2022
- ***Percentage complete:*** 15%

Budget

- ***Total:*** $4,214,135
  - ***Govt. Share:*** $3,207,135
  - ***Cost-share:*** $1,007,000

Barriers & Technical Targets

Reference: Vehicle-Mobility Systems Analysis Tech Team (VMSATT) Roadmap

Target Outcome 1: Develop framework for estimating energy, emissions, and cost benefits of vehicle technologies under research and development (Vehicle System)

Target Outcome 2: Quantify and validate with real-world data the energy savings benefits of optimized advanced vehicle control (Vehicle System)

Target Outcome 3: Explore and quantify the benefits of intelligent intersection platforms with and without connected and automated vehicle technologies (Infrastructure)

Partners

- ***Tier-1 partner:*** Continental Inc.
- ***OEM partner:*** Hyundai-Kia America Technical Center, Inc.
- ***Tech-To-Market partner:*** Frost & Sullivan
- ***Outreach partner:*** Alamo Area Clean Cities Coalition

Relevance

- **Energy Efficient Mobility Systems (EEMS) Subprogram Goal**
  - Identifying critical pathways and developing innovative technology solutions to enable significant *improvements in mobility energy productivity* when adopted at *scale*

- **Program Objectives**
  - Achieve *15% energy savings* via connectivity and automation algorithms on a mixed fleet of vehicles with respect to powertrain type and automation levels
  - Understand *system impact* of this smaller fleet of ‘smart’ vehicles on overall traffic at different levels of technology penetration
  - Leverage an *intelligent intersection platform* to bring information about non-connected players and potentially offload on-board computation on highly automated vehicles to help reduce processing power

Relevance – Alignment with EEMS Roadmap

- Develop a simulation framework for accurately estimating energy consumption benefits for eco-driving technology in a mixed fleet of vehicles with different powertrain technology (internal combustion engine, hybrid-electric, pure electric) and varying levels of automation (L0 – L4)

- Quantify and validate energy consumption benefits measured in simulation via real vehicle tests

- Quantify the impact of intelligent infrastructure systems on energy consumption of a vehicle convoy across a corridor

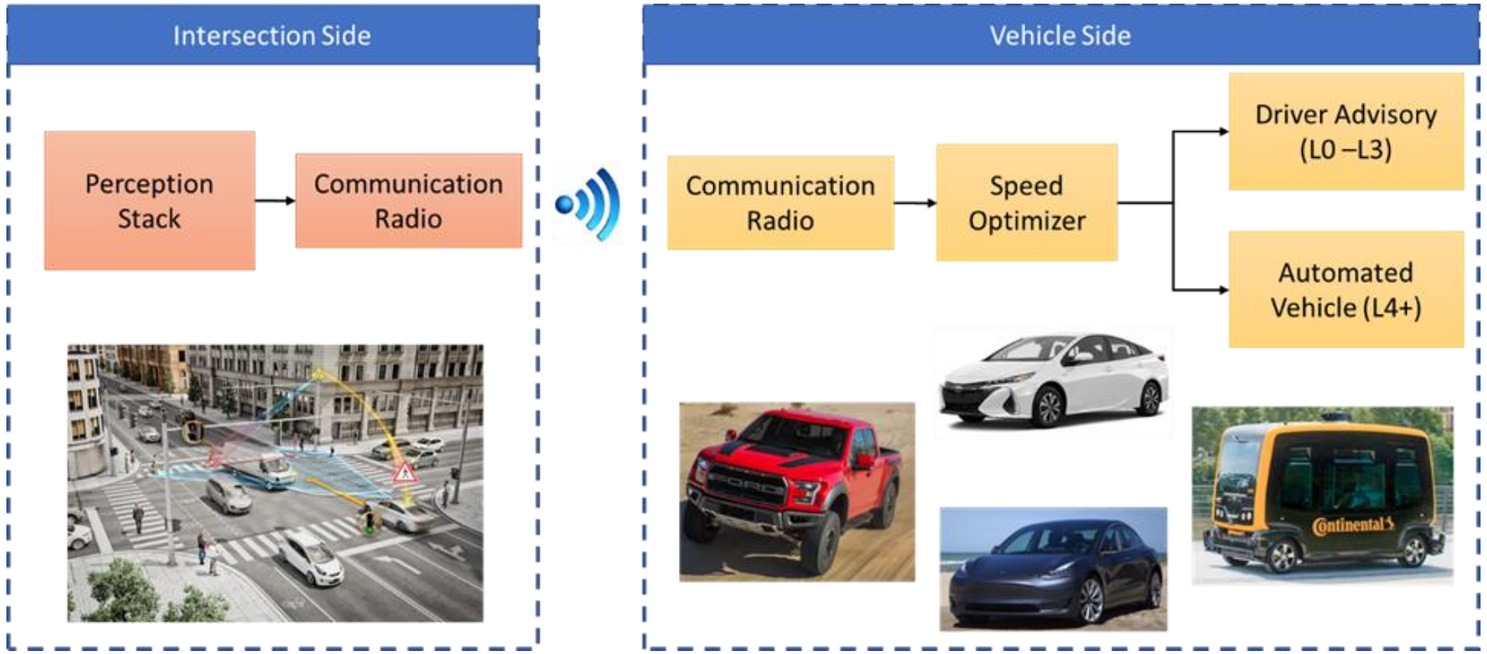
Milestones – FY2020

Milestone	Description	Type	Status
Road network for traffic simulation validated	Road network for traffic simulation complete.	Technical	On Track
Macroscopic traffic simulation validated	Demonstrate relevant metrics from simulation within 10% of measured value.	Technical	On Track
Traffic simulation with intersection functionality validated	Completion of the initial version of traffic simulation with intersection-based traffic mix. This would be validated with real data recorded at intersections.	Technical	On Track
Vehicle & powertrain models for energy consumption on transient drive cycles validated	Completion of initial vehicle and powertrain models for the vehicle mix selected for the program. Validation will be using dynamometer or Environmental Protection Agency (EPA) published (effective) fuel consumption on standard test cycles.	GO/NO-GO	On Track

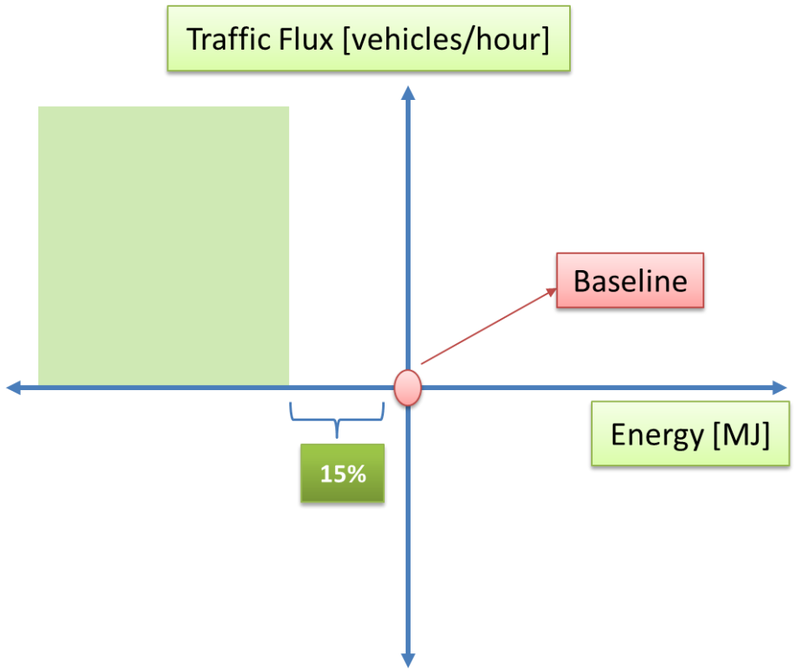
Milestones – FY2021

Milestone	Description	Type	Status
Intersection stack validated with real traffic data	Validate operation of the intersection stack with real traffic data.	Technical	**In Progress**
Demonstrate 15% energy savings via proposed methodology in simulation	Final demonstration of energy consumption benefits in simulation for overall fleet.	Technical	**Not Started**
First draft of Techno-Economic-Analysis complete	Generate a cost performance model that provides insight into the trade-offs and interactions between product design, cost and performance.	Technical	**Not Started**
Demonstrate 10% energy savings on a Connected Automated Vehicle (CAV) dynamometer	Demonstration of energy consumption benefits on a hub dynamometer integrated with a real-time traffic simulator.	**GO/NO-GO**	**Not Started**

Approach



Powertrain	Automation Levels					
		L0	L1	L2	L3	L4
	ICE	Hyundai				Continental
	HEV					
	PHEV			Hyundai		
	EV			Hyundai		Continental



- Connectivity common theme across ‘smart’ vehicle fleet
- Leverage intersection stack to communicate scene understanding
- Speed optimization leveraging Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) info and information stack → Energy savings
- Savings propagate to non-connected vehicles enabling system level benefits

Key Modules – FY2020

Simulate velocity trajectories for all vehicles

3

Intelligent Intersection

Sensing | *Perception* | *Processing* | *Comms*

1

V2V: distance, speed
V2I: distance to light, phase, time remaining in phase

Eco-Driving (x 5)

*Optimal Speed**

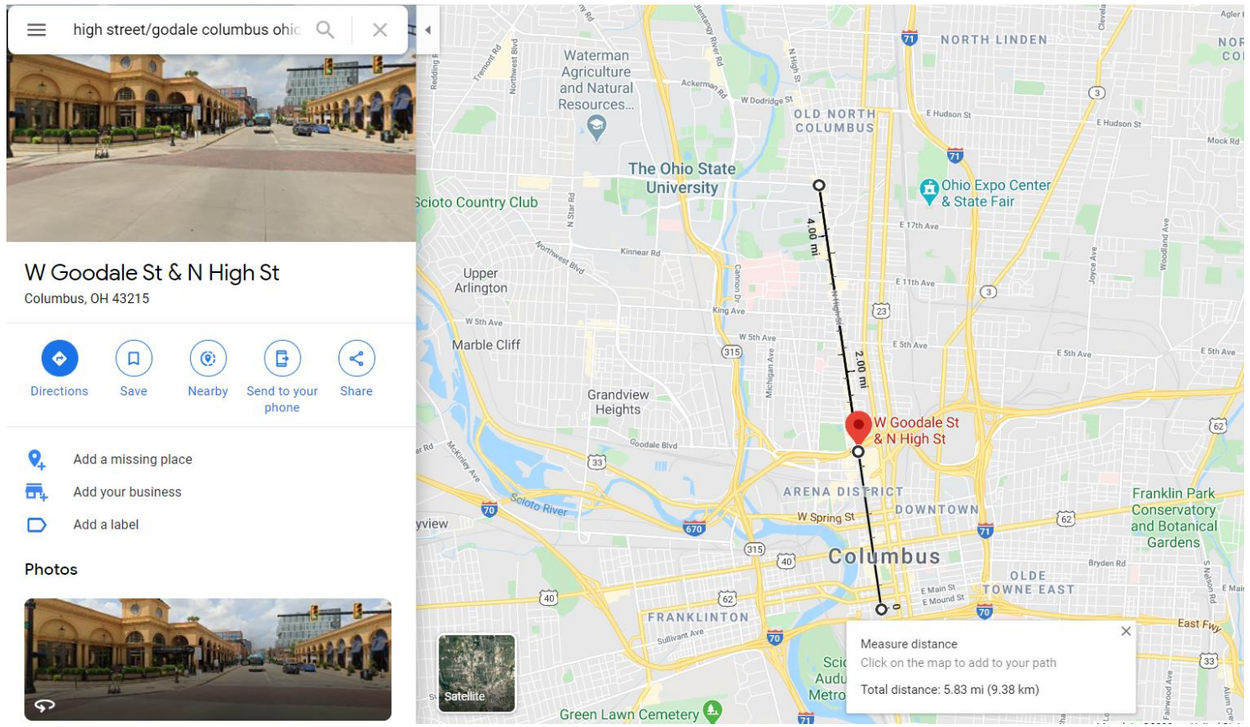
2

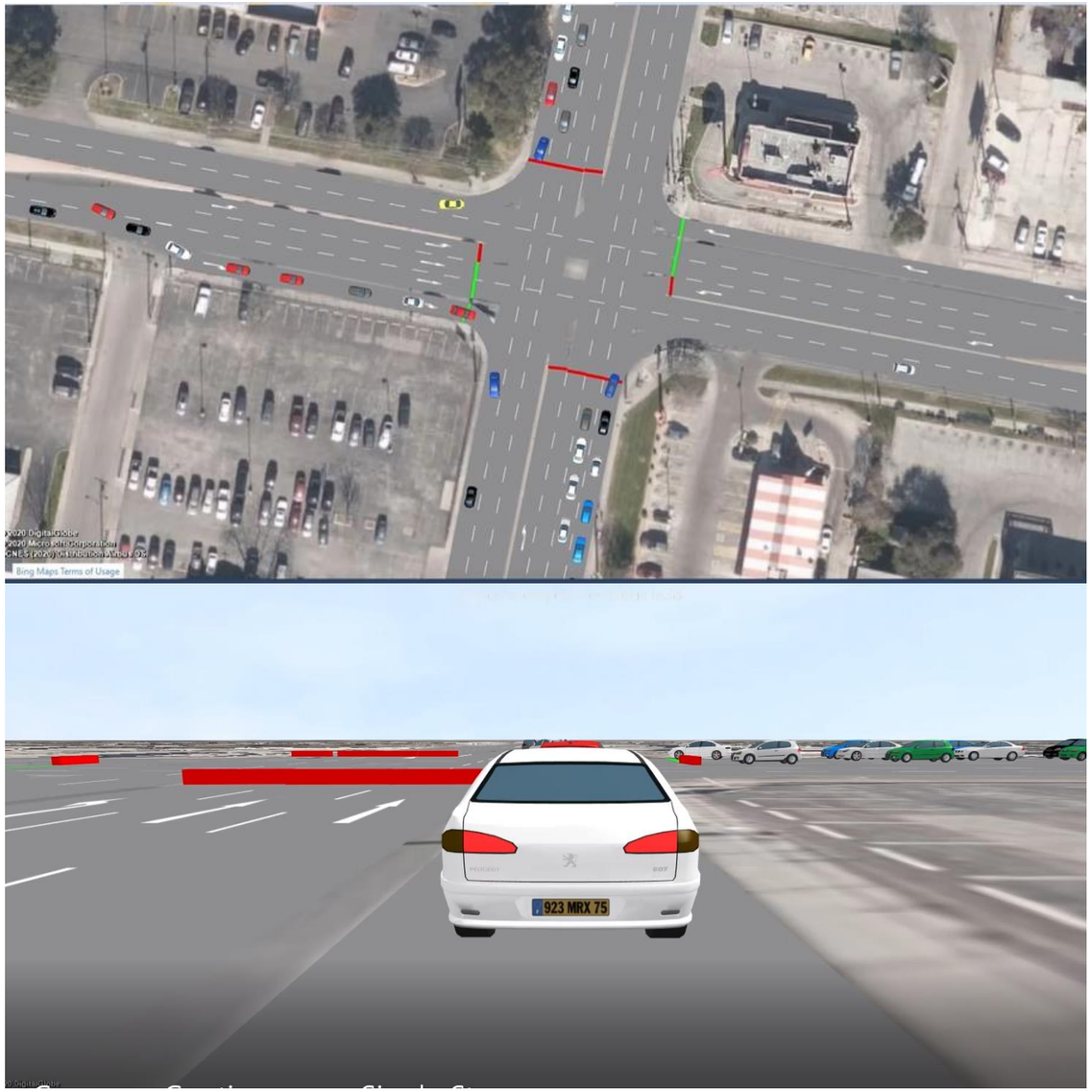
Time, Speed trace for all vehicles

Vehicle Simulator

Energy Consumption

Traffic Simulation





- PTV Vissim selected as traffic simulation platform post evaluation by team
- Corridor selection in progress: Columbus, OH Auburn Hills, MI and San Antonio, TX

Vehicle Simulation

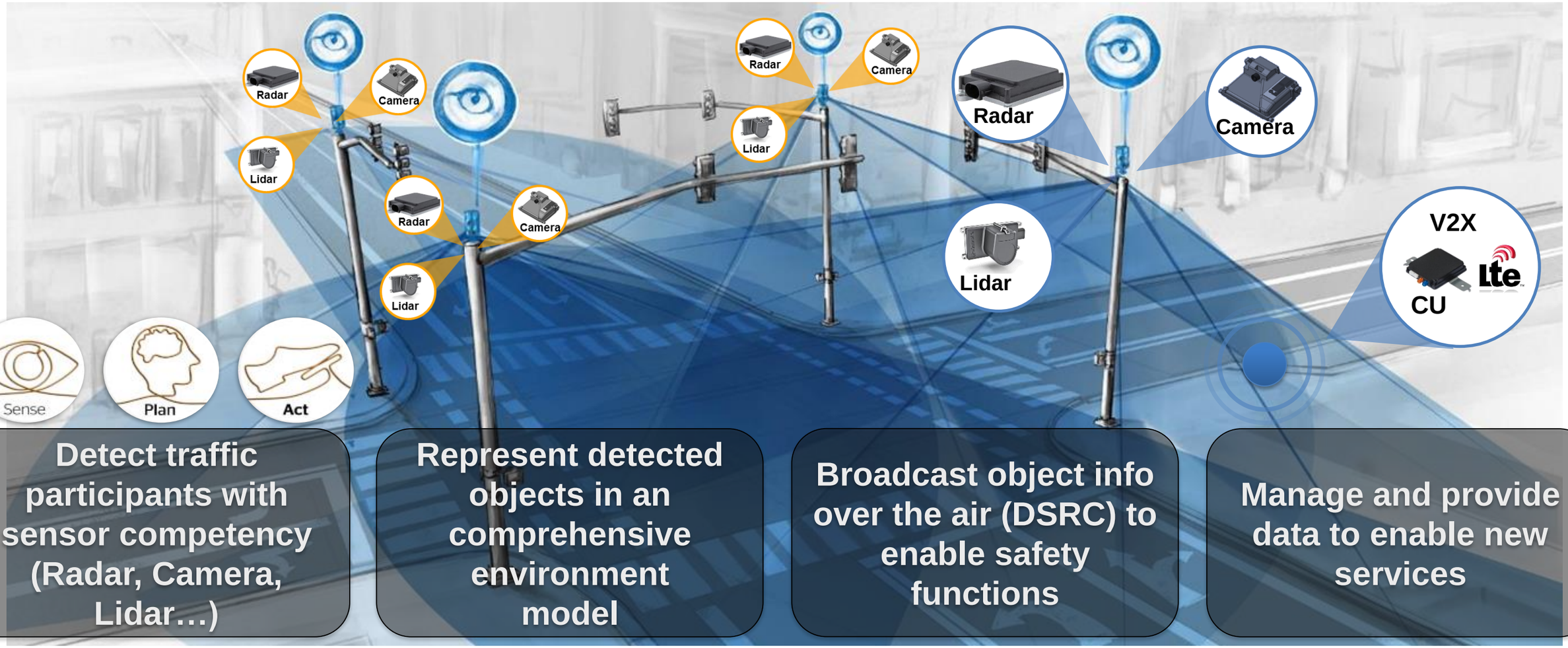
- Require high-fidelity powertrain models for accurately capturing energy consumption benefits of eco-driving across fleet
- Procured Autonomie from Argonne National Lab
- Access to existing vehicle models in GT-Suite and Simulink
- Modeling PHEV powertrain complex – accurate modeling of power-split strategy in addition to component modeling
  - Leverage SwRI/Autonomie models
- Team deciding on unified platform that enables batch simulation
- Hyundai to provide full access to vehicle CAN data
- Continental facilitating meetings with Easy Mile on vehicle data

Vehicle Simulation Platforms

- Selected vehicle platforms:
  - L0 ICE: Hyundai Elantra
  - L2 PHEV: Toyota Prius Prime
  - L2 EV: Hyundai Kona/Ioniq
  - L4 ICE: Chrysler 300
  - L4 EV: Easy Mile EZ10

		Automation Levels				
		L0	L1	L2	L3	L4
Powertrain	ICE	Hyundai				Continental
	HEV					
	PHEV			Hyundai		
	EV			Hyundai		Continental

Intelligent Intersection - Vision Zero



Detect traffic participants with sensor competency (Radar, Camera, Lidar…)

Represent detected objects in an comprehensive environment model

Broadcast object info over the air (DSRC) to enable safety functions

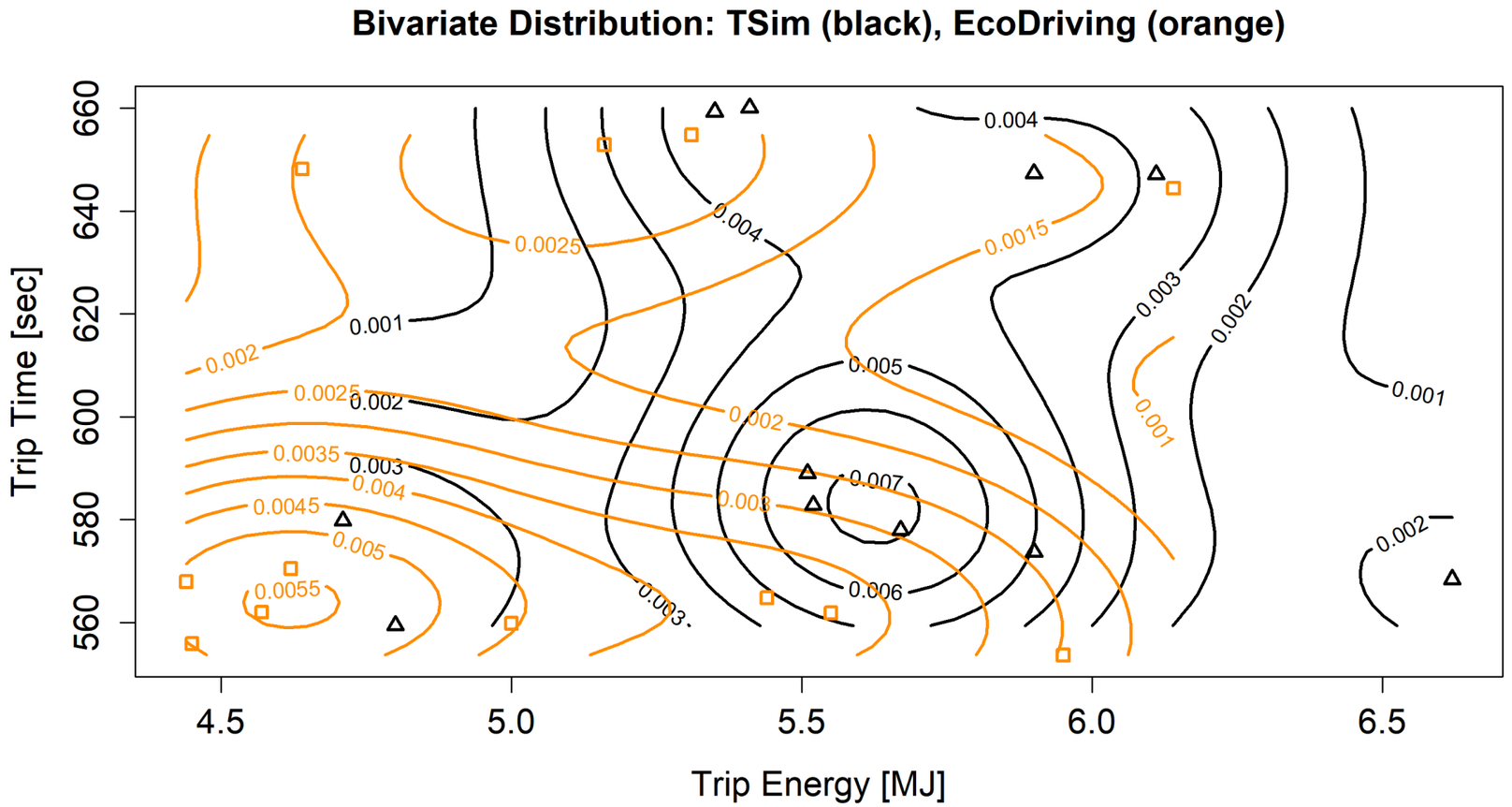
Manage and provide data to enable new services

Continental
The Future in Motion

POWERTRAIN ENGINEERING

swri.org

Eco-Driving Individual Vehicle Results

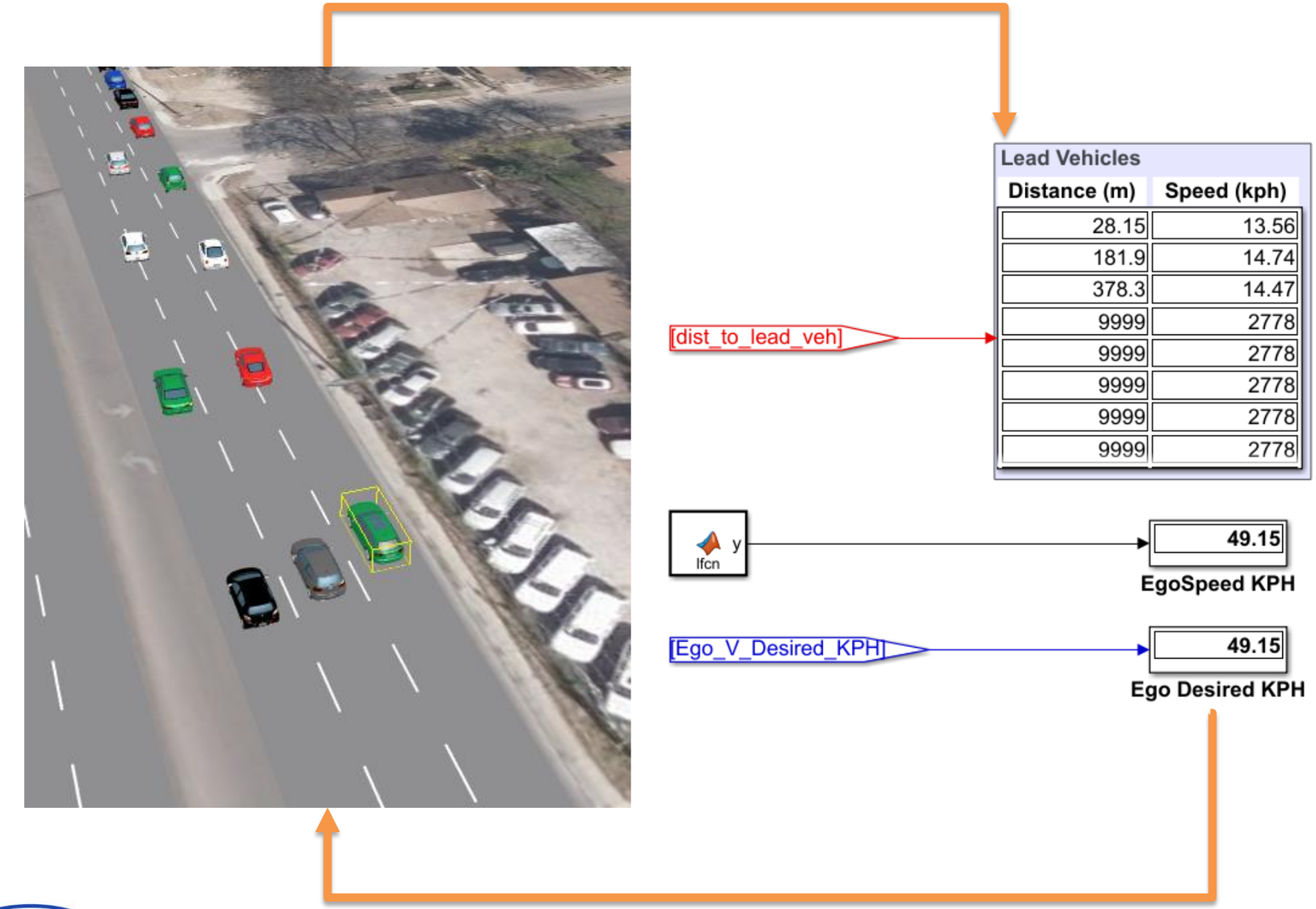


SwRI NEXTCAR Program Results

- ❑ Individual vehicle focus
- ❑ Baseline mean = [5.6 MJ, 604 s]
- ❑ Eco-Driving mean = [5.1 MJ, 591 s]

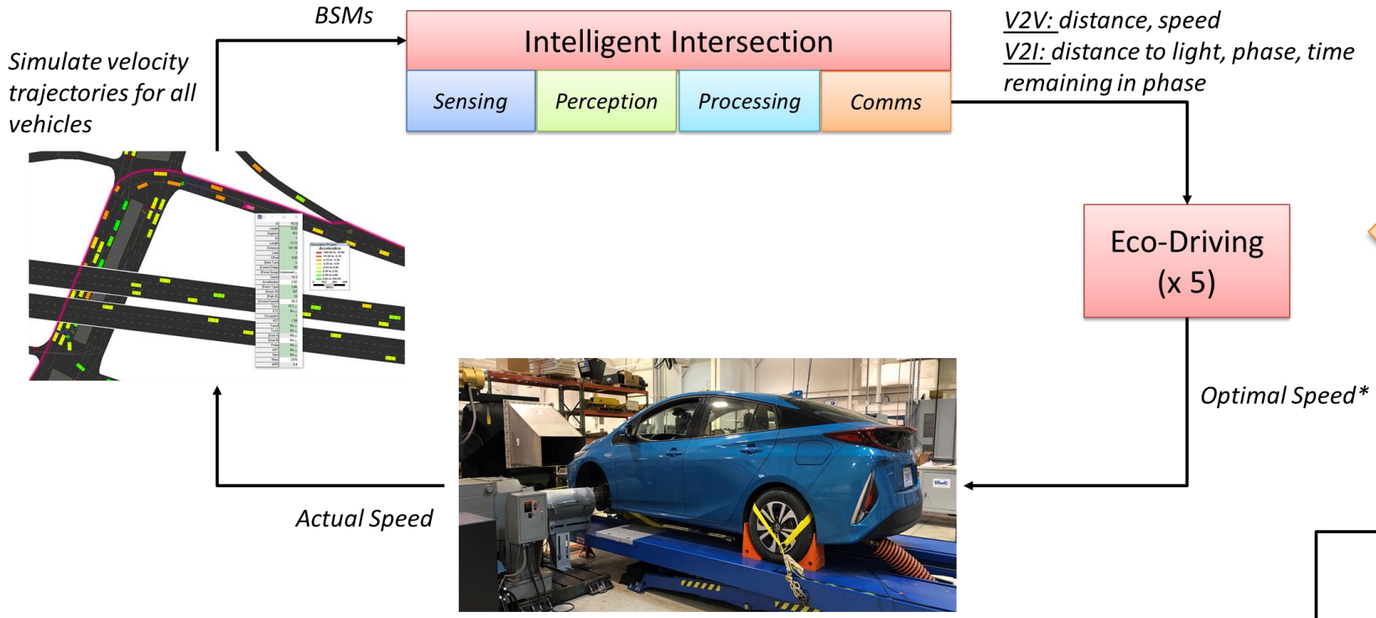
Nominal benefits ~ 10% energy consumption *without negatively impacting trip times*

Eco-Driving Integration with Traffic Simulator



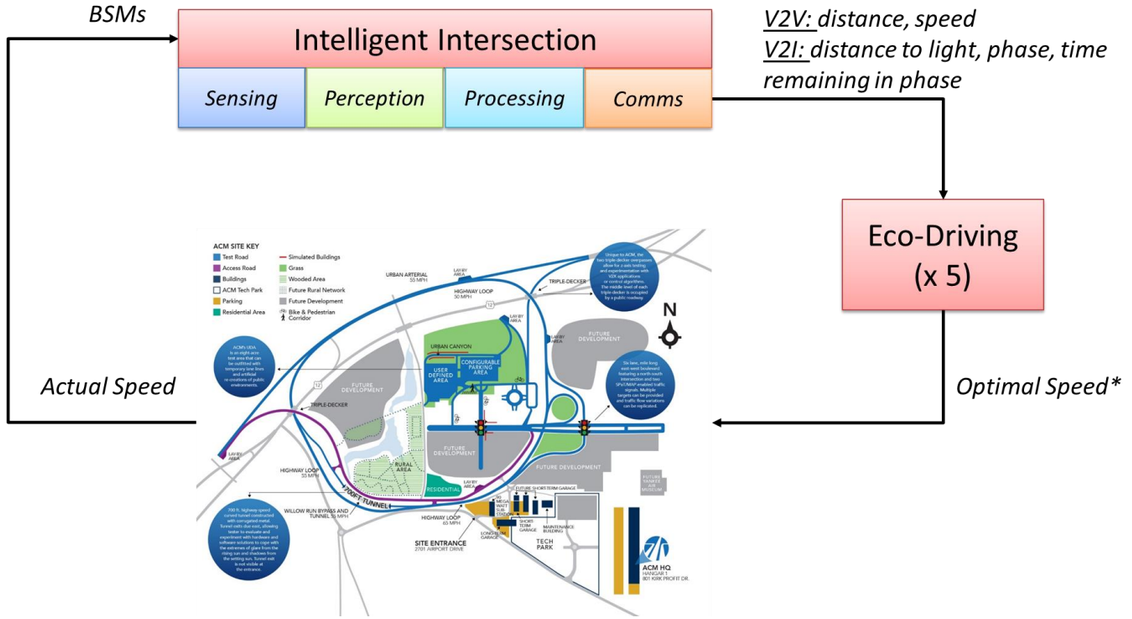
- Acquire V2V and V2I data
- Ego vehicle(s) controlled via external command
- Deterministic performance testing (10 Hz or better)
- Lane level identification and filtering of vehicles

Plan for FY2021 and FY2022



FY2021: Transition from Simulation to CAV Dynamometer

FY2022: Transition from dynamometer to track testing



Response to Previous Year Reviewer's Comments

- This is the first year the project has been reviewed

Collaboration & Coordination

Partner	Partnership Type	Role
Continental	Subrecipient	Integral member of technical team providing Level 4 prototypes and intelligent intersection platform.
Frost & Sullivan	Subrecipient	Integral member championing Tech-2-Market milestones along with market research and driver clinic studies. Focus on how public sector can contribute to this area.
Hyundai-Kia America Technical Center, Inc.	Collaborator	OEM partner providing guidance, vehicles and identifying synergies with other connected vehicle programs like smart cities and Crash Avoidance Metrics Partners (CAMP).
Alamo Area Clean Cities Coalition	Industry Partner	Facilitate meetings with public sector entities in Texas and help be an outreach partner for the technology.

Barriers & Challenges

- Calibrate traffic simulation to realistic baseline scenarios
- Intersection stack validation with real data and long range conditions (~300 m from intersection)
- Optimize eco-driving algorithm to scale for multiple ego vehicles
- Optimize user interface for driver advisory system
- Integrate advisory system with DSRC On-Board-Units (OBUs)
- Integrate with Level 4 vehicle controls architecture to implement eco-driving and other control algorithms

Proposed Future Research

- FY2020 (Simulation focus)
  - Complete traffic simulation network for real corridor
  - Leverage traffic flux data from public deployments of intersection stack to calibrate traffic simulation
  - Test and validate vehicle simulation platform

- FY2021 (Vehicle testing on dyno focus)
  - Integrate traffic simulator with vehicle dynamometer
  - Vehicle instrumentation and testing on closed loop setup
  - Achieve 10% improvement in energy consumption on dynamometer

Summary

- Program in early stages
  - DOE contract with SwRI finalized 03/25/2020
  - SwRI finalizing subcontracts and IP plans with partners
  - Weekly calls with team to stay connected in COVID times
- FY2020 focus on simulation study
  - Making progress on traffic simulation and vehicle simulation
  - Leveraging real-world data as much as possible (ex: traffic flux data from Continental intersection stack deployments in OH/MI)
- Looking ahead:
  - FY2021 Vehicle on CAV dynamometer
  - FY2022 Track testing